LEARNER WORKSHEET · PAGE 1

Predict what the planet will keep

Driving question. Can two worlds that receive the same starlight have very different atmospheres five billion years later?

Both model runs start with the Close-in flare world preset. The planet orbits the same red dwarf at 0.12 AU and starts with the same surface pressure and oxygen share. Run A uses Flare-active. Run B changes only Stellar activity to Quiet. Keep oxygen replenishment off in both.

Task 1 · Predict before running

Which run will retain more atmosphere? Will incoming starlight change? Explain your prediction. Identify the variable you change and two conditions you hold fixed.

Prediction and variables

Task 2 · Collect evidence

Open the lab, select the preset, and record the starting values. Play five billion years for Run A. Change only Stellar activity to Quiet, then play Run B from year zero. Open the history and result card after each run. The 3D view is optional. For paper use, read the offline observations on page 2.

Record a starting value and compare the two outcomes.

Measure	Start, both runs	Run A at 5 billion years	Run B at 5 billion years
Incoming starlight (× Earth)	____	____	____
High-energy exposure (× Earth)	A ____ / B ____	____	____
Atmosphere remaining (%)	____	____	____
Temperature (°C or °F)	____	____	____
Oxygen partial pressure (bar)	____	____	____

LEARNER WORKSHEET · PAGE 2

Calculate, compare, and defend a claim

Offline observations

Both runs receive 1.39 times Earth's starlight. The high-energy exposure index is 16.7 for Run A and 1.4 for Run B. These numbers are simulated.

Selected model observations for the paper activity.

Run	Age (billion years)	Air left	Temperature	O_2 partial pressure
Both	0	100%	30 °C / 86 °F	0.210 bar
A · Active	2.5	28%	12 °C / 54 °F	0.008 bar
A · Active	5	8%	7 °C / 45 °F	0.000 bar (rounded)
B · Quiet	2.5	94%	29 °C / 84 °F	0.027 bar
B · Quiet	5	88%	27 °C / 81 °F	0.003 bar

Task 3 · Predict an orbit

At 0.12 AU the orbital period is 27.7 Earth days. For the same star, period scales as distance raised to the 3/2 power. Predict the period at 0.24 AU. Use the inverse-square rule to predict the incoming starlight at 0.24 AU. Show both scaling factors.

Orbit and starlight calculations

Task 4 · Claim, evidence, reasoning, and limits

Can equal incoming starlight tell you whether a planet keeps its air? Support a claim with two readings. Explain why the temperatures diverge and why the quiet run's retained air does not establish breathable conditions. State one limit of the model.

Claim and evidence

Exit check

At 0.50 bar total pressure and an oxygen share of 21%, what is the oxygen partial pressure? Show the multiplication.

Calculation

EDUCATOR NOTES · PAGE 3

Facilitate and score the investigation

Audience. Grades 9-12, with an introductory-college extension. Learners should know percentages, ratios, and square roots. Allow 50-60 minutes. Provide the learner pages only during the investigation. Learners can use the lab's text readouts or work entirely from the printed observations.

1. Predict and identify variables (8 min).

2. Run both cases or read the offline table (15 min).

3. Calculate orbital period and starlight (10 min).

4. Write and discuss claims, then complete the exit check (17-27 min).

Answer key and acceptable ranges

Ranges allow for rounding or reasonable reading of the display. Grade the direction of change, units, and reasoning alongside the values.

Acceptable ranges for the five-billion-year endpoints.

Measure	Run A · Active	Run B · Quiet
Incoming starlight (× Earth)	1.38-1.40	1.38-1.40
High-energy exposure (× Earth)	16.6-16.8	1.38-1.41
Atmosphere remaining	7-9%	87-89%
Surface temperature	6-8 °C / 43-47 °F	26-28 °C / 79-83 °F
O_2 partial pressure	0.000-0.001 bar	0.003-0.004 bar

Task 1. Run B retains more atmosphere. Incoming starlight is unchanged. Accept any two correctly identified fixed settings, such as host star, orbit, mass, starting pressure, or oxygen replenishment.

Task 2. Both runs begin with 100% of their initial atmosphere, 29-31 °C (84-88 °F), and 0.209-0.211 bar oxygen partial pressure. A rounded reading of 0.000 bar in Run A allows for a small positive modeled value.

Task 3. Doubling the distance multiplies the period by $2\sqrt{2} \approx 2.83$, giving about 78.4 days. Accept 78-79 days. Starlight drops to one-quarter, about 0.35 × Earth. Accept 0.34-0.36 × Earth.

Exit check. 0.50 × 0.21 = 0.105 bar. Accept 0.10-0.11 bar with valid rounding and work shown.

EDUCATOR NOTES · PAGE 4

Reasoning, assessment, and extension

Task 4 · Example of full-credit reasoning

Both planets receive about 1.39 × Earth's starlight, but the quiet run retains about 88% of its atmosphere and the active run retains about 8%. In this model, high-energy exposure accelerates gas loss. Less gas means less modeled greenhouse warming, so Run A cools more. Run B still has very low oxygen partial pressure because its oxygen share declines without replenishment. The model assigns illustrative escape rates and uses one global temperature, so these runs cannot predict a real planet's future.

Suggested 12-point rubric

Score each criterion from 0 to 3.

Criterion	Full credit (3)
Prediction and control	States a prediction, identifies the changed variable, and names two fixed conditions.
Observations	Records results for both runs within the accepted ranges, with units.
Quantitative reasoning	Uses the two scaling rules and calculates oxygen partial pressure with units.
Scientific explanation	Uses two readings, explains gas loss and cooling, and identifies a limit.

Award 2 for mostly correct work with a minor omission, 1 for partial evidence of understanding, and 0 for missing or unsupported work.

Standards and extension

NGSS HS-ESS1-4 connection. Task 3 uses a mathematical representation of orbital motion to predict a period. The larger activity practices using models, interpreting data, and constructing explanations. The fictional system supports practice with the same two-body reasoning used in the solar-system performance expectation.

Introductory college. Estimate each run's atmospheric loss timescale using the model relationship t / ln(1/f), where f is the remaining fraction. Using displayed five-billion-year pressures of about 0.081 and 0.883 bar as proxies for retention, expect about 2.0 and 40.2 billion years. Accept 1.9-2.1 and 39-42 billion years. Compare the result with one assumption that could change it.

Scientific sources and reuse

NASA · The Habitable Zone · NASA Exoplanet Archive · Incident flux and equilibrium temperature · NGSS · HS-ESS1-4

Original lesson text and generated exercise data are licensed CC BY-NC 4.0. Attribute Lance Jepsen, The Last Transmission, with the lesson title and URL. Site artwork, software, and linked sources are excluded. Classroom validation and independent accessibility review are pending.